Chapter Two: Geography and General Information

Contents

Chapter Two: Geography and General Information

This chapter describes the property and ownership status for uplands and tide and submerged lands in the Beaufort Sea Areawide sale. This is followed by a review of the oil and gas exploration and leasing history and a general description of the petroleum potential of the region, concluding with the current leasing status of the sale. The physical characteristics of the region are described with an emphasis on dynamic processes of the Beaufort Sea coast. It is the interactive coastal zone which provides the energy and nutrient supplies for habitats, and their dependent fish, wildlife, and human populations, which are described in Chapter Three.

A. Property and Ownership Description of the Sale Area

1. Property Description

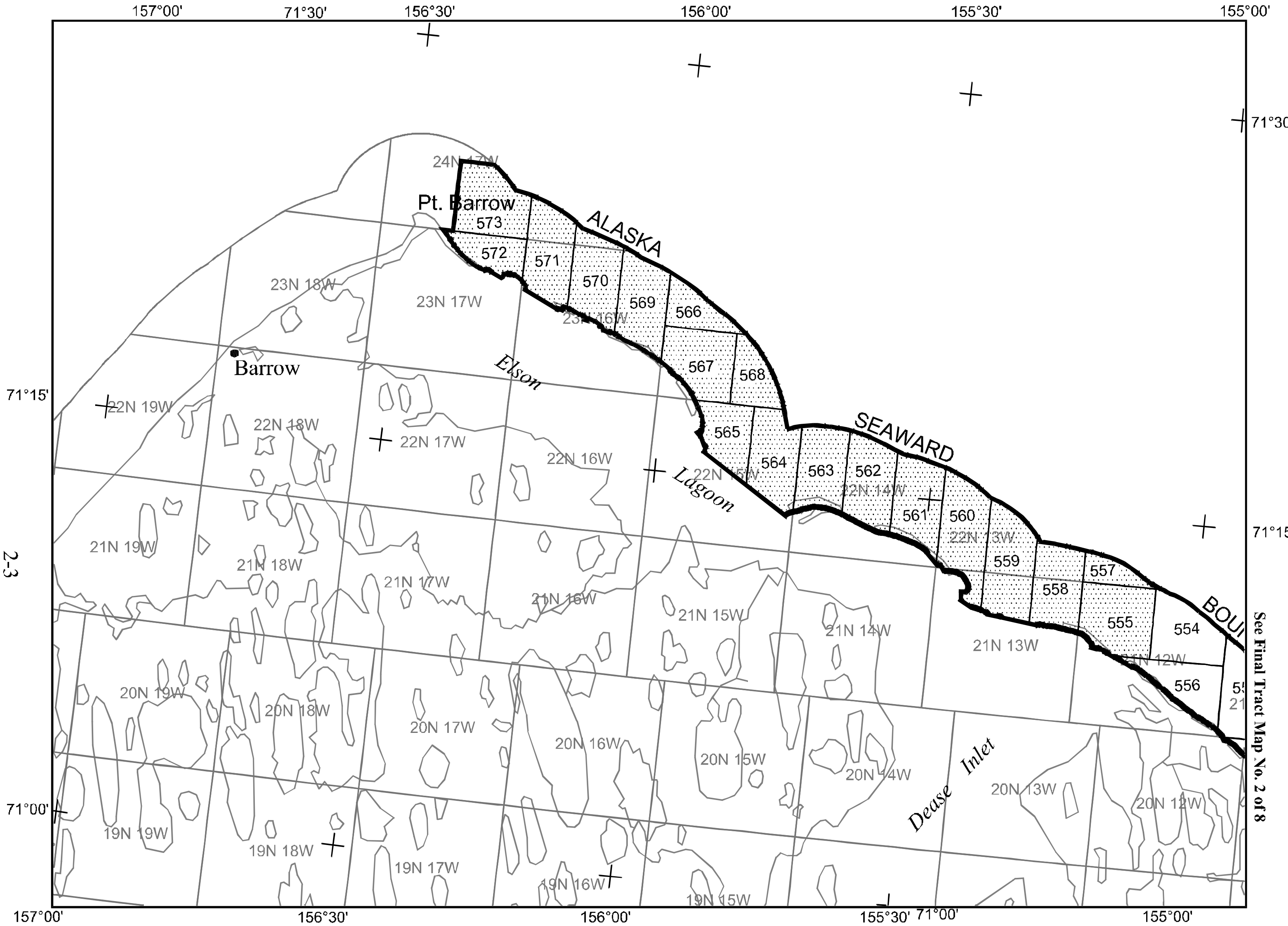
The sale area contains as much as 2,000,000 acres in 573 tracts and consists of coastlands, nearshore and submerged land, located along the Beaufort Sea coast, from Barrow to the Canadian border. The sale area also includes numerous islands (See Tract Maps, Figures 2.1.A - 2.1.H). The Alaska Department of Natural Resources (ADNR) has deleted Tracts 573-575 from the final finding, and renumbered Tract 576 as 573. Deletion means these tracts are not covered by this best interest finding and will not be offered for lease in the next 10 years. ADNR has deferred from this sale all tracts from Pt. Barrow to Tangent Point (Tracts 555, 557-573) and from Barter Island to Canada (Tracts 1-39). Deferral means that these tracts will not be offered for lease in the 1999 areawide sale, but may be included in future lease sales. Even though existing mitigation measures (Chapter Seven) provide the necessary protection for subsistence activities, ADNR is taking the extra precaution of removing these tracts from consideration at this time. In addition, it seems unlikely that these tracts would be immediately subject to development. It is possible that during the 10-year period covered by this finding, the prospects for developing these tracts will increase. ADNR will annually review the available information for these lease tracts to determine whether to offer them in the future.

With the exception of tidelands off the Arctic National Wildlife Refuge (ANWR), the state owns all of the tidelands within in the sale area, subject to resolution of the Dinkum Sands dispute. The state, Bureau of Land Management (BLM), Minerals Management Service (MMS), and U.S. Fish and Wildlife Service (USF&WS) have reached a tentative agreement covering a majority of the disputed area. The remaining portion is still in negotiation and, therefore, the boundary is subject to change.

The state owns most of the upland portion of the sale area (between the Staines and Colville Rivers). The subsurface estate of seven onshore tracts within the Colville River Delta is owned jointly by state and the Arctic Slope Regional Corporation (ASRC), with Kuukpik Corporation as the surface owner. There is one federal inholding, the DEW site at Bullen Point. Although surrounded by the sale area, this acreage is excluded from state leasing because the state does not own the subsurface estate. There are several native allotments and parcels owned by the North Slope Borough. The state, as the subsurface owner, may lease these lands. Uplands from the Canning River to the Canadian border lie within ANWR, which is owned by the federal government and, therefore, not subject to leasing. Kaktovik-Inupiat Corporation, the village corporation for Kaktovik, and ASRC, also own land in this area. Uplands from the Colville River to Barrow are within the National Petroleum Reserve-Alaska (NPR-A), which is owned by the federal government, and, therefore, not included in state lease sales.

Prominent waterbodies included in the sale area include Smith Bay, Harrison Bay, Simpson Lagoon, Gwyder Bay, Prudhoe Bay, Stefansson Sound, Foggy Island Bay, Mikkelson Bay, and Camden Bay. Important island groups include Plover, Jones, Return, Midway, McLure, Stockton, Maguire and Flaxman Islands.

The entire area is within the North Slope Borough Coastal Zone. This home rule borough, incorporated in 1972, extends from the Chukchi Sea to the Canadian border. The borough has the powers of taxation, land management and zoning, and is responsible for providing borough communities with public works, utilities, education, health, and other public services. Borough residents rely heavily on the sale area for subsistence resources.



State of Alaska
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Beaufort Sea Areawide 1999 Oil And Gas Lease Sale

Final Tract Map No. 1 of 8

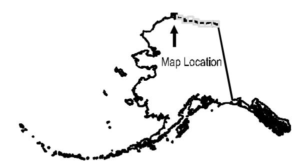
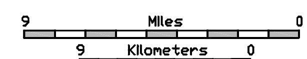
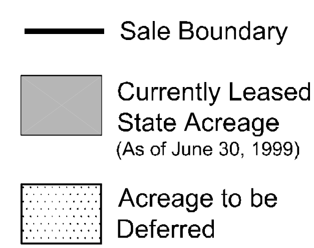


FIGURE 2.1.A





This map is not an official tract map, but is for informational purposes only. DNR makes no claim as to its accuracy. Bidders are solely responsible for determining the availability of acreage prior to submitting a bid.

Note: Discrepencies In the Alaska Seaward Boundary are the result of different data sources.

Albers Equal-Area Conic Projection, 1927 North American Datum, Clarke 1866 ellipsoid with a central meridian of 148° 45', origin latitude of 50°, northern parallel of 65°, and southern parallel of 55°.

Director, Division of Oil and Gas	Leasing Manager
Kenneth A. Boyd ________ Date: ____	James Hansen ________ Date: ____

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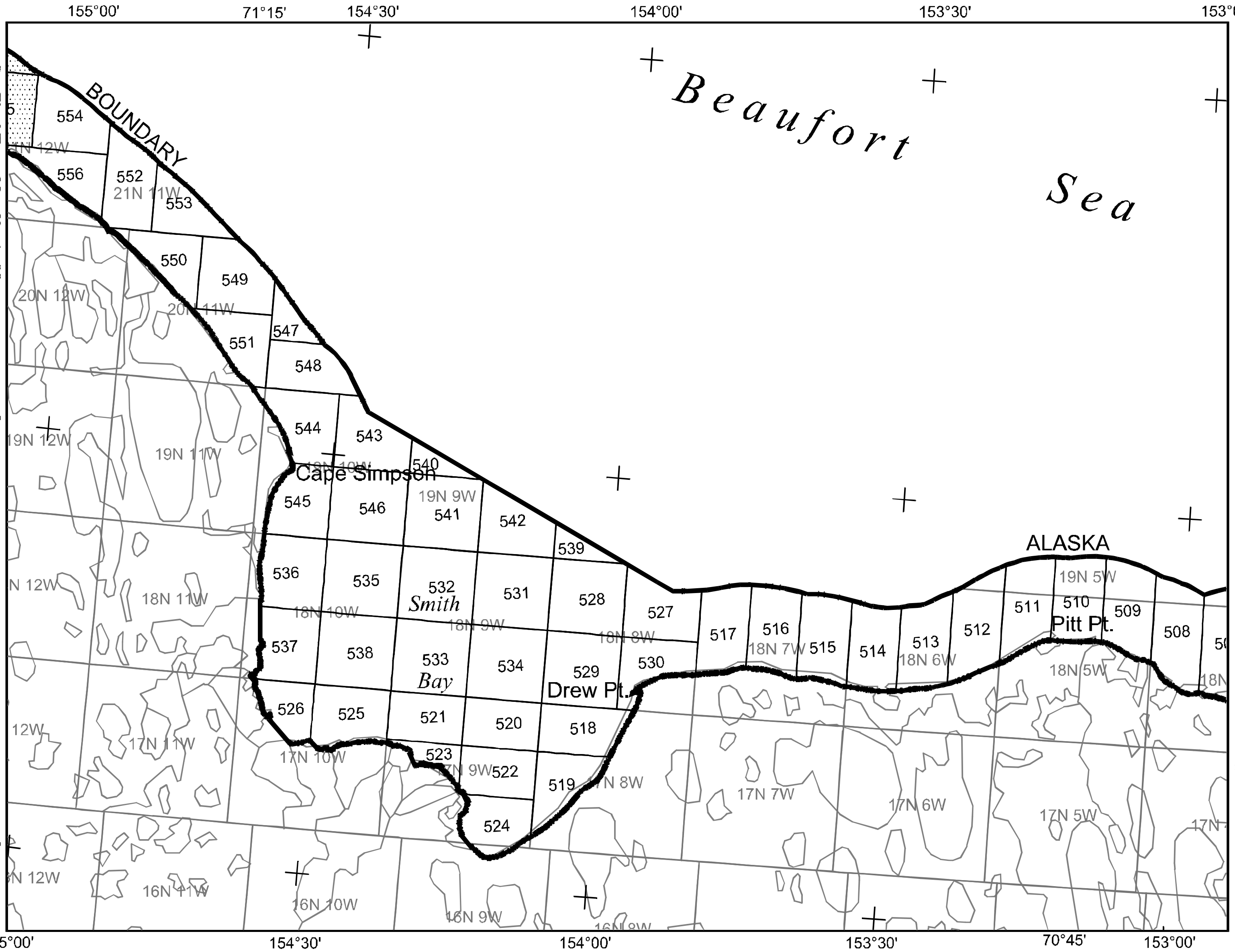
Beaufort Sea Areawide 1999 Oil And Gas Lease Sale

Final Tract Map No. 2 of 8

See Final Tract Map No. 1 of 8



See Final Tract Map No. 3 of 8

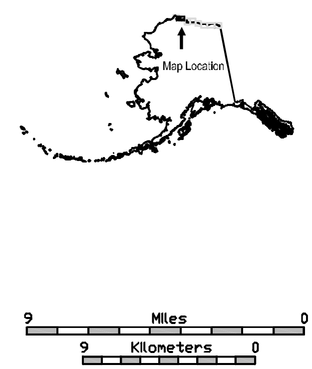


FIGURE 2.1.B

Sale Boundary

Currently Leased State Acreage (As of June 30, 1999)

Acreage to be Deferred

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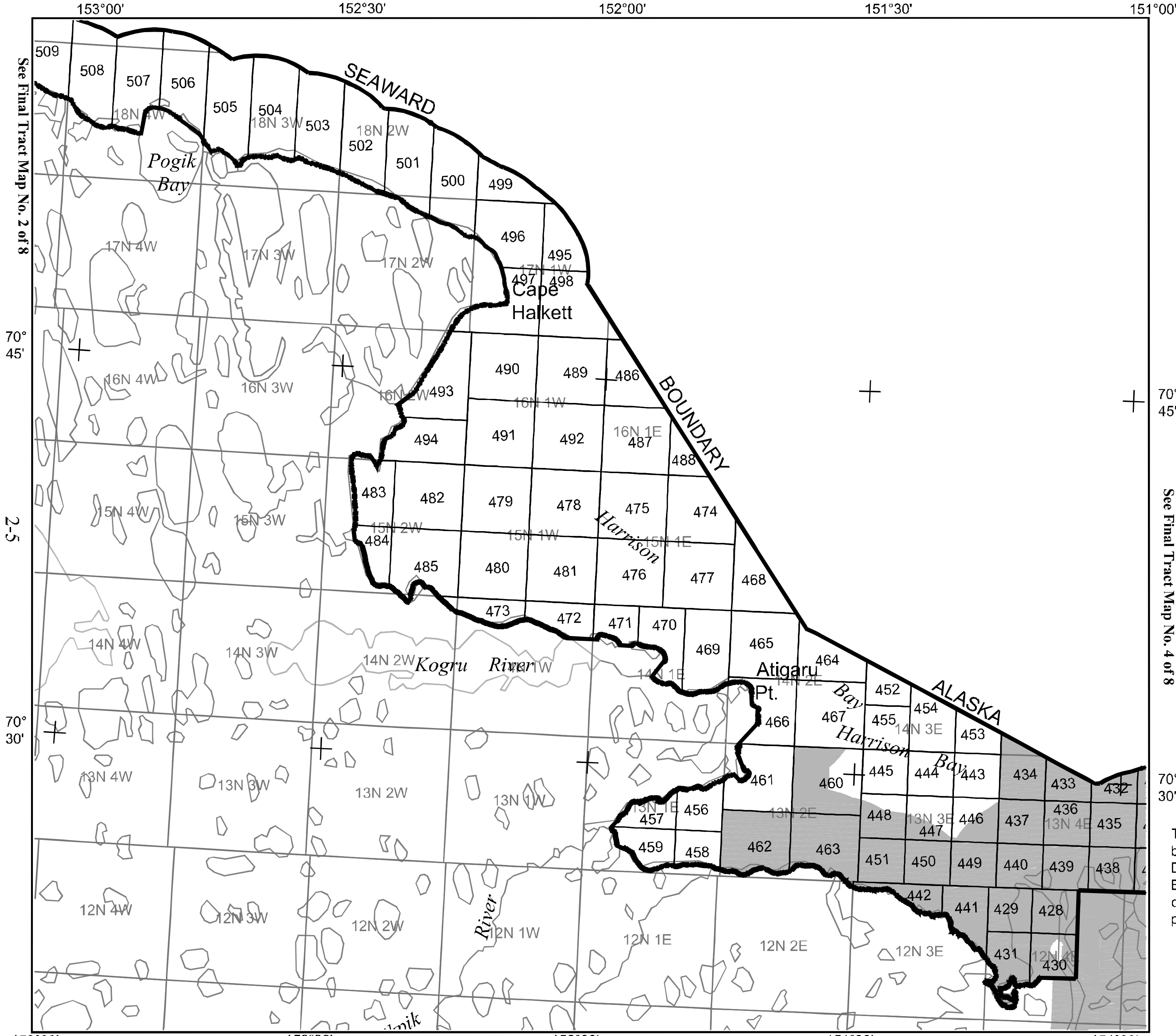
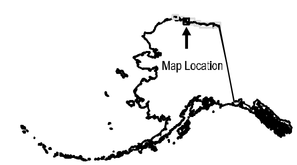


See Final Tract Map No. 2 of 8

See Final Tract Map No. 4 of 8



Sale Boundary

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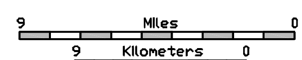

Albers Equal-Area Conic Projection, 1927 North American Datum, Clarke 1866 ellipsoid with a central meridian of 148° 45', origin latitude of 50°, northern parallel of 65°, and southern parallel of 55°.

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FIGURE 2.1.C

State of Alaska
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Beaufort Sea Areawide 1999 Oil And Gas Lease Sale

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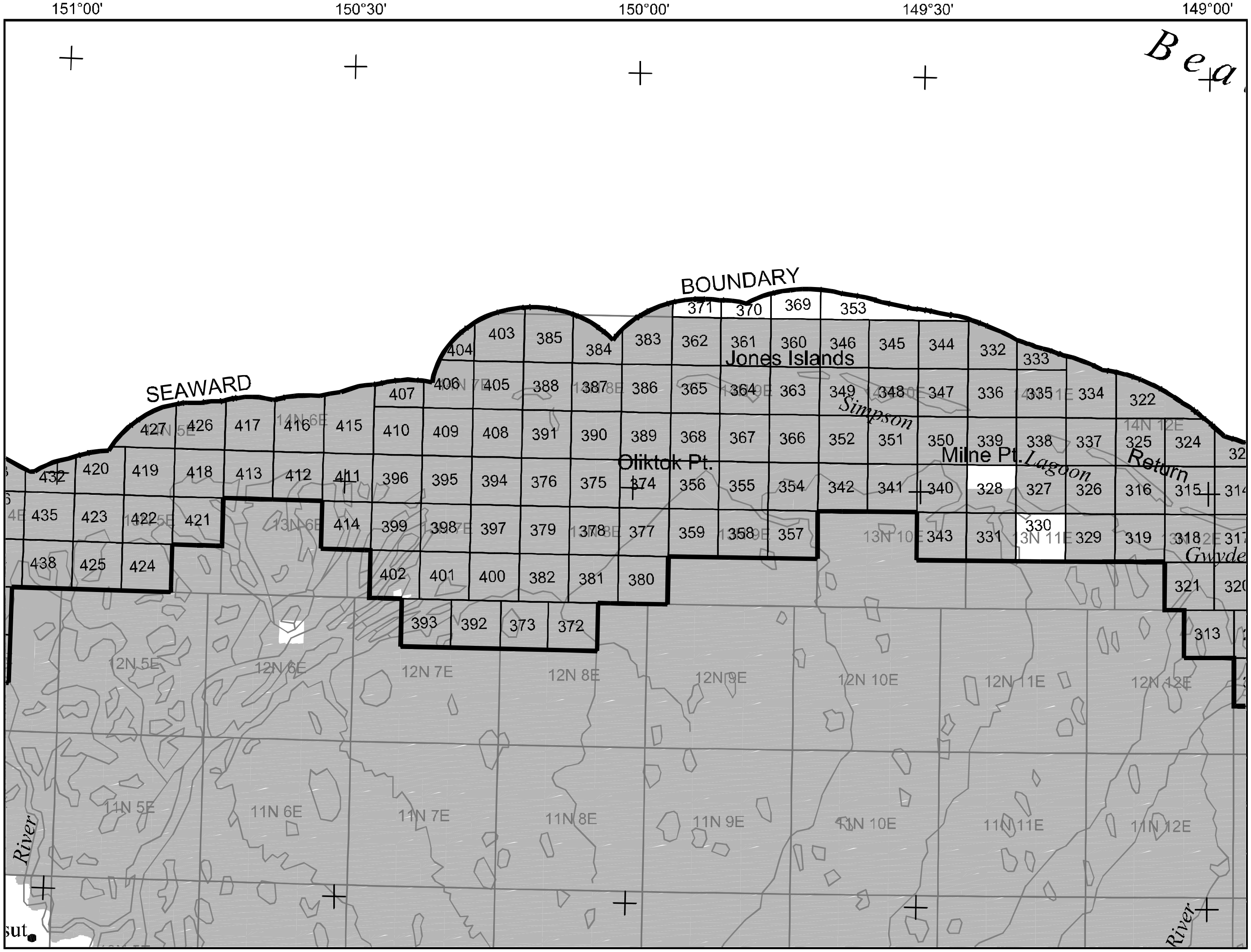
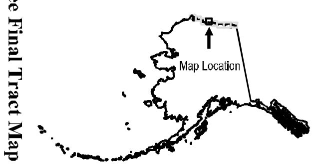


See Final Tract Map No. 3 of 8

See Final Tract Map No. 5 of 8



Miles 9 0
Kilometers 9 0

Sale Boundary

Currently Leased State Acreage (As of June 30, 1999)

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Director, Division of Oil and Gas	Leasing Manager
Kenneth A. Boyd ________ Date: ____	James J. Hansen ________ Date: ____

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FIGURE 2.1.D

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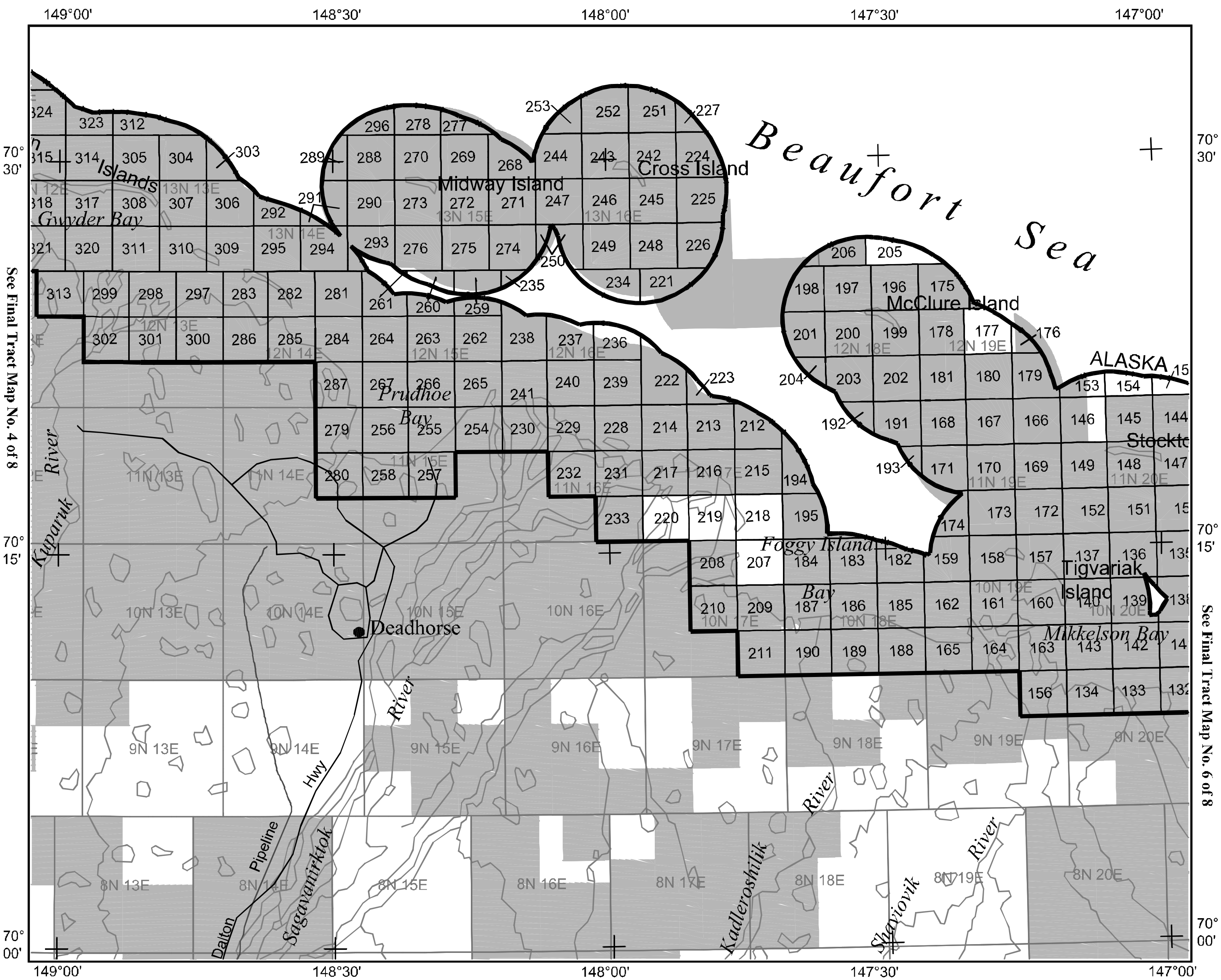

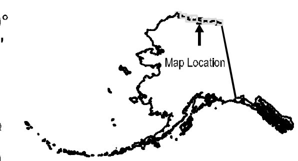

Sale Boundary

Currently Leased State Acreage (As of June 30, 1999)

Miles 9 0
Kilometers 9 0

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FIGURE 2.1.E

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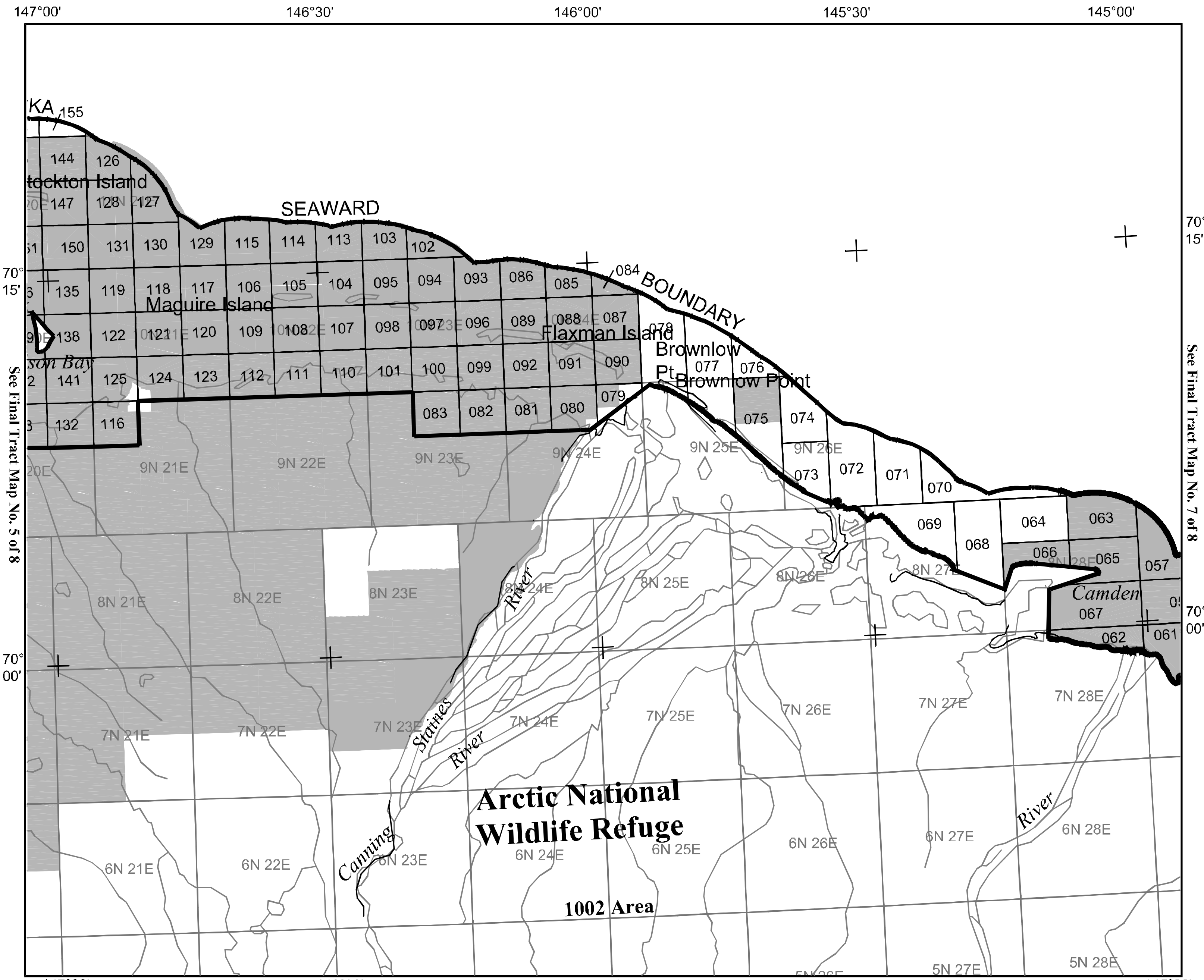
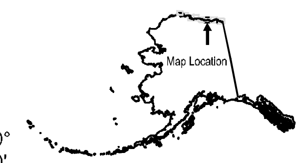
See Final Tract Map No. 7 of 8



See Final Tract Map No. 5 of 8



Sale Boundary

Currently Leased State Acreage
(As of June 30, 1999)

9 Miles 0
9 Kilometers 0

This map is not an official tract map, but is for informational purposes only. DNR makes no claim as to its accuracy. Bidders are solely responsible for determining the availability of acreage prior to submitting a bid.

Director, Division of Oil and Gas	Leasing Manager
Kenneth A. Boyd ______________ Date: ______	James J. Hansen ______________ Date: ______

Note: Discrepencies In the Alaska Seaward Boundary are the result of different data sources.

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FIGURE 2.1.F

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Beaufort Sea Areawide 1999 Oil And Gas Lease Sale

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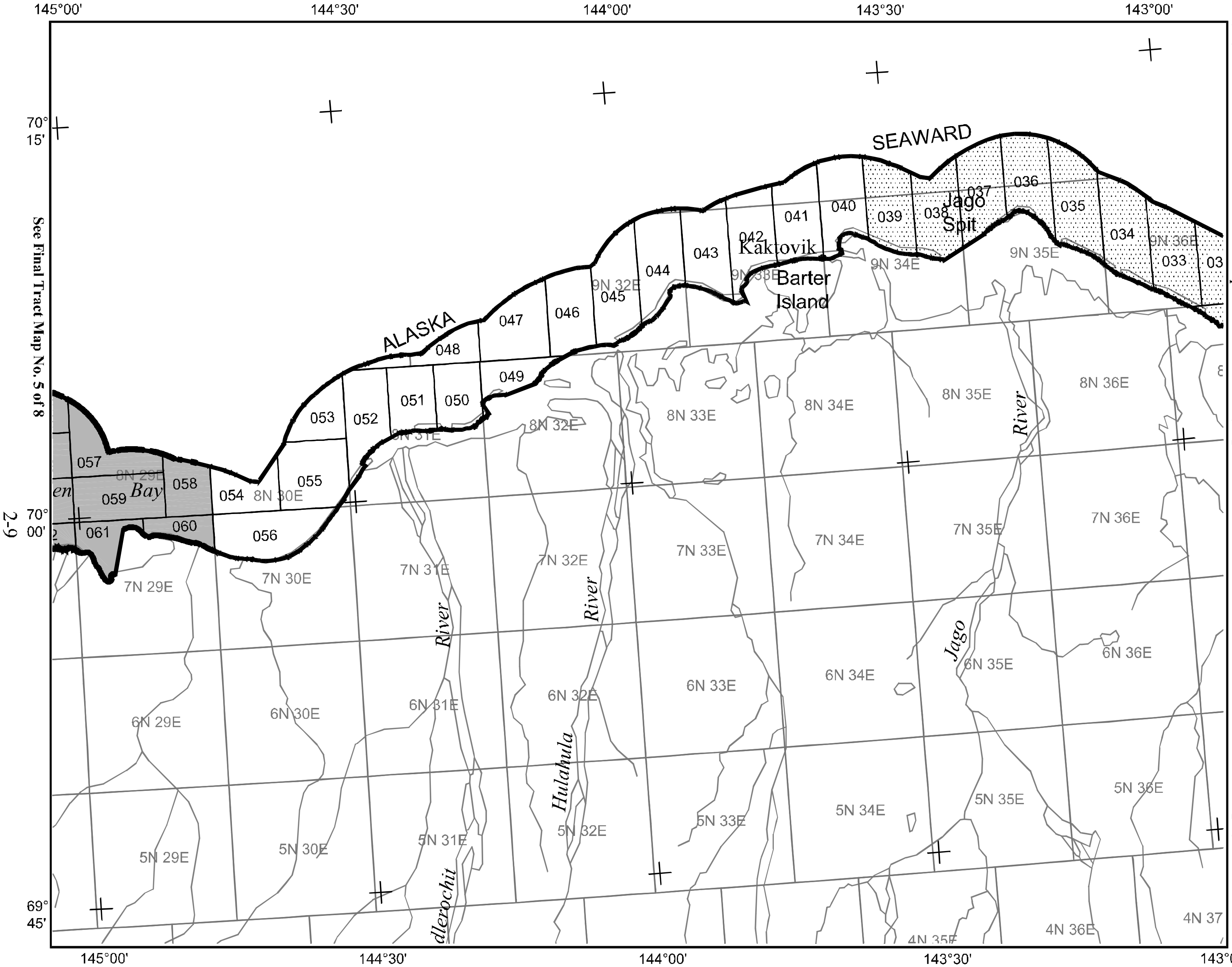

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Albers Equal-Area Conic Projection. 1927 North American Datum, Clarke 1866 ellipsoid with a central meridian of 148° 45', origin latitude of 50°, northern parallel of 65°, and southern parallel of 55°.

Director, Division of Oil and Gas	Leasing Manager
Kenneth A. Boyd ______________________ Date: ________	James J. Hansen ______________________ Date: ________

FIGURE 2.1.G

State of Alaska
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Oil And Gas Lease Sale Beaufort Sea Areawide 1999

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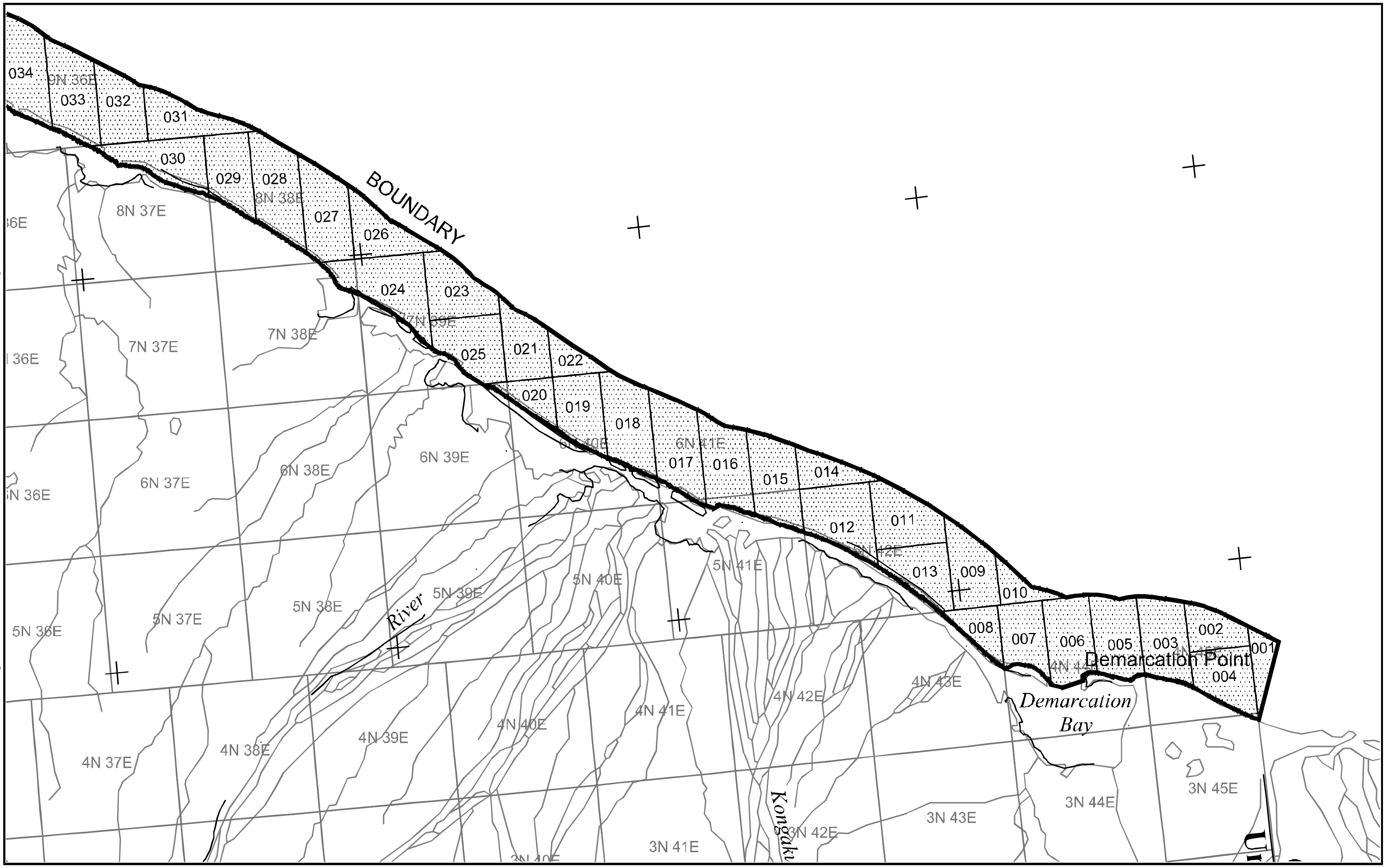

See Final Tract Map No. 7 of 8

Albers Equal-Area Conic Projection, 1927 North American Datum, Clarke 1866 ellipsoid with a central meridian of 148° 45', origin latitude of 50°, northern parallel of 65°, and southern parallel of 55°.

9 Miles 0
9 Kilometers 0

Note: Discrepencies In the Alaska Seaward Boundary are the result of different data sources.

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Director, Division of Oil and Gas	Leasing Manager
Kenneth A. Boyd ______ Date: ______	James J. Hansen ______ Date: ______

Sale Boundary
Currently Leased State Acreage (As of June 30, 1999)
Acreage to be Deferred

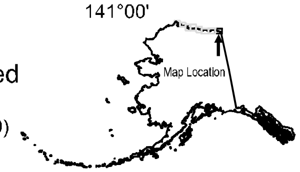


FIGURE 2.1.H

Physical Characteristics of the Sale Area

1. Geology

Northern Alaska is composed of three distinct physiographic provinces: the Brooks Range; the Arctic Foothills; and the Arctic Coastal Plain (Moore, et al., 1994, figure a). The sale area contains acreage that is located in the Arctic Coastal Plain region within the North Slope Structural Province. The North Slope Structural Province forms the modern northern continental margin of Alaska.

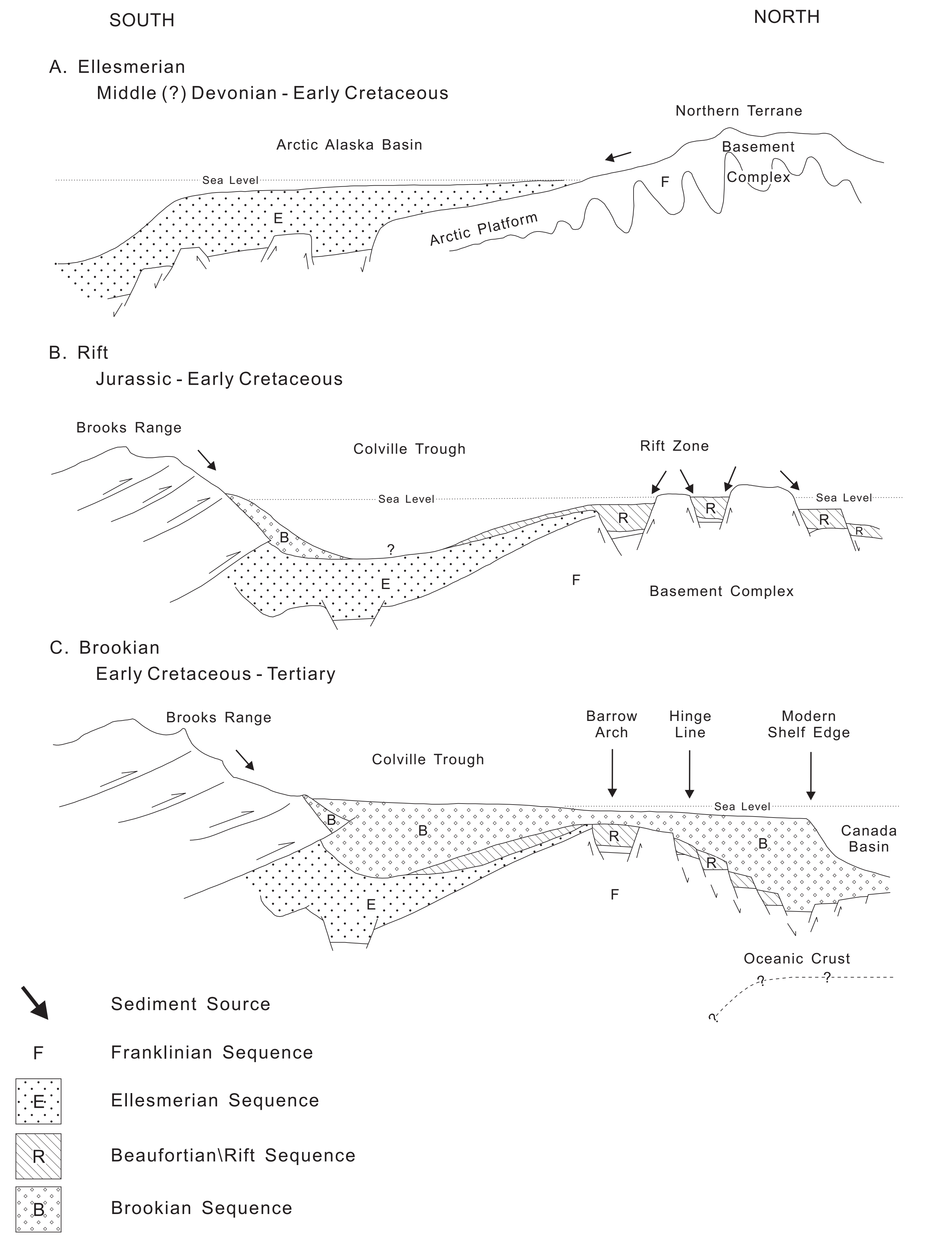
The geologic history of the sale area includes periods of plate collisions, continental rifting, regional uplift, episodes of major regional erosional scour, and sedimentary deposition. Northern Alaska has four major geologic sequences of rocks, each having a unique structural setting, provenance (sediment source area), and depositional environment. During the deposition of each of these major geologic sequences, smaller scale events, such as changes in sea level and differential amounts of basin subsidence, have altered and shaped the depositional environments, sculpturing local internal complexities within each of the four major sequences. The four major rock sequences from oldest to youngest (older rocks are deposited first and in the absence of structural complexities are stratigraphically lower): the Franklinian, Ellesmerian, Beaufortian Rift, and the Brookian. The structural events that shaped the evolution of the North Slope Structural Province were (Figure 2.2):

1. A stable early continental platform before Devonian time;
2. Onset of continental rifting during the Late Jurassic through Early Cretaceous time, with uplift to the north of this stable Arctic Platform and deposition of sediments southward; and
3. Continued rifting, uplift, and termination of deposition from the north, along with uplift of the Brooks Range and deposition of sediments from the south onto the Arctic Coastal Plain during the Early Cretaceous through Tertiary time.

The Franklinian (pre-Mississippian) sequence was once a stable continental platform before Middle Devonian time (about 400 million years ago). Pre-Mississippian rocks of the Franklinian sequence comprise the oldest rock sequence that underlies the Arctic Coastal Plain region. The Franklinian Sequence consists of fractured carbonate, argillite, quartzite, volcanic, and granitic rocks that were deformed, uplifted, and eroded during Cambrian through Devonian time. During the Late Devonian time, the Franklinian sequence was uplifted. Erosion off the uplifted Franklinian high provided the northerly source of sediments for the Ellesmerian sequence. The highly metamorphosed and fractured rocks of the Franklinian Sequence have limited petroleum potential, most likely only as fractured reservoirs.

The Ellesmerian Sequence contains marine carbonates and quartz- and chert-rich clastic rocks that were deposited over a 150 million year period on a subsiding foldbelt terrain (Hubbard, 1987) during the Mississippian through Early Jurassic time. The Ellesmerian thins to the south due to depositional distance from its source and thins to the north due to subsequent uplift and erosion (Moore, et al., 1994). The Permo-Triassic Ivishak Formation was deposited within the Ellesmerian sequence as a large fan-delta complex. It forms the reservoir for the giant Prudhoe Bay Oil Field that has produced over 12 billion barrels of oil.

The modern northern continental margin of Arctic Alaska has been shaped by structures that were formed as a result of Jurassic to Early Cretaceous rifting events that created the Barrow Arch, a structural high that has dominated the structural and depositional history of the area (Moore, et al., 1994). Rifting of the continental mass dominated the geology of the North Slope by the end of the late Jurassic to late Cretaceous periods. The northern continental source for the Ellesmerian sediments supplied less and less sediment to the Arctic Basin as time passed. Uplift and faulting of the Franklinian and Ellesmerian sequence formed normal fault blocks, consisting of horst and grabens. The grabens were filled with sediments from nearby locally uplifted or block-faulted Ellesmerian and Franklinian sequences, forming the Beaufortian Rift Sequence (Craig, et al., 1985). At this time, the Barrow Arch formed along the present day Beaufort Coast. Sedimentation from the north eventually ended in the Late Cretaceous.



Source: Craig and others, 1985

FIGURE 2.2

The following period of non-deposition along with continued uplift along the Barrow Arch created a regional scouring event known as the Lower Cretaceous Unconformity (LCU) which becomes angular where approaching the Barrow Arch from the south. Ellesmerian strata were progressively uplifted, subaerially exposed, eroded and truncated in a northeasterly direction along the emerging Barrow Arch during the Late Jurassic and Early Cretaceous. The LCU stripped off significant amounts of Ellesmerian strata and resulted in the creation of enhanced porosity, creating excellent hydrocarbon reservoirs in the formations that lay directly under this angular unconformity. The regional erosional activity of the LCU is one of the most significant geological events with regards to the creation of secondary porosity in potential reservoir rocks as well as creating a conduit for the migration of oil and gas into these enhanced porosity reservoirs. In general, the Ellesmerian formations that are prolific oil producers such as the Kuparuk 'A' Sandstones and the Ivishak and Kekiktuk formations, directly underlie the LCU.

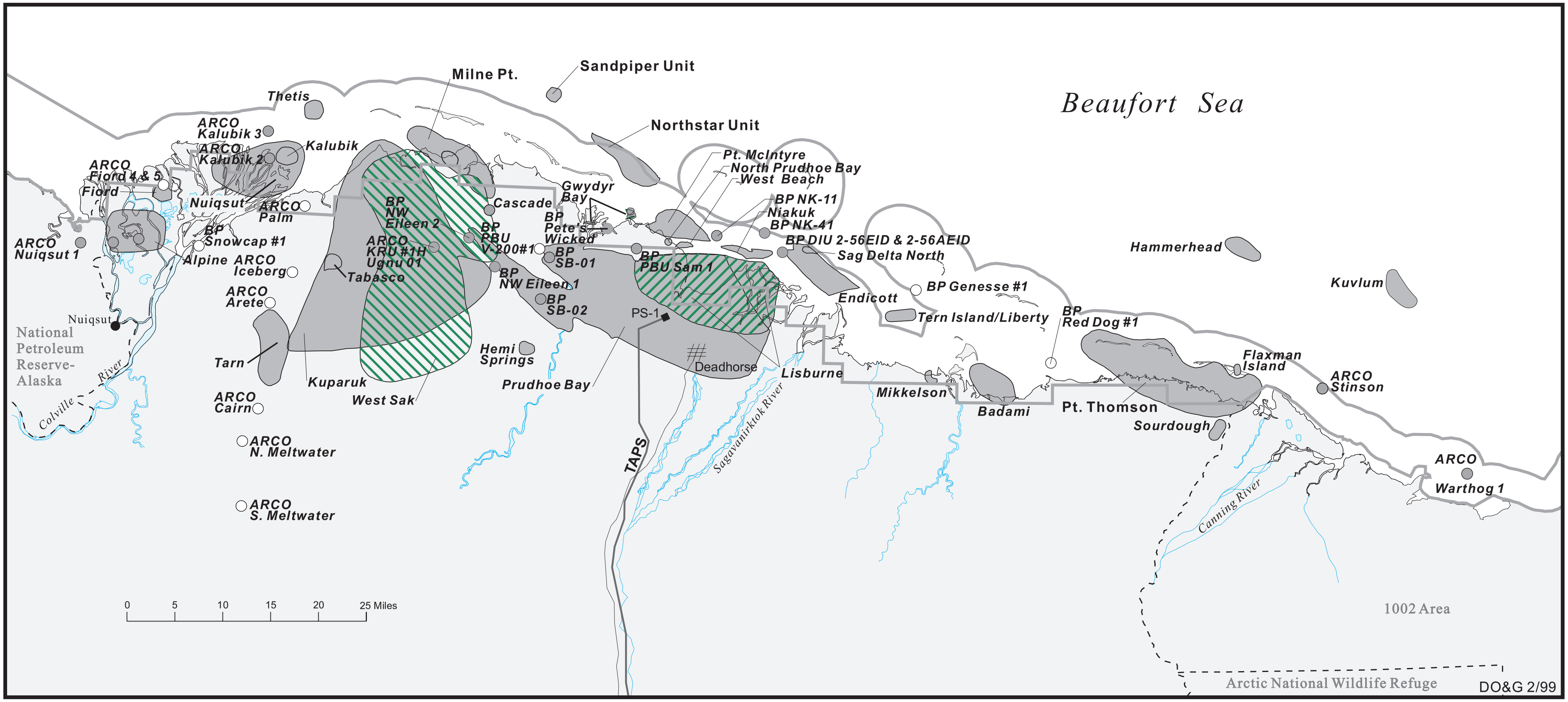
Following the uplift and erosion of the Ellesmerian section by the LCU along the Barrow Arch, the Arctic Coastal Plain was buried by marine shales, siltstones, and sandstones of the Beaufortian Rift Sequence. Oil and gas traps within the Beaufortian Rift sequence include purely stratigraphic traps as well as combination structural/stratigraphic traps that were formed by the sequence of rift events. Many of the Beaufortian Rift sandstones that directly overlie the LCU such as the Kuparuk 'C' and Alpine sandstones are prolific North Slope oil reservoirs. The rift-derived sediments of the Beaufortian Sequence contain many known oil and gas accumulations (see Figure 2.3) such as the Kuparuk River, Milne Point, Pt. McIntyre, Niakuk, Alpine, and Pt. Thomson fields as well as discoveries in the Colville Delta area such as the Texaco Colville Delta, Fiord, and Kalubik wells. Known gas accumulations are present within this interval in NPR-A with the East Barrow, South Barrow, Sikulik, and Walakpa fields.

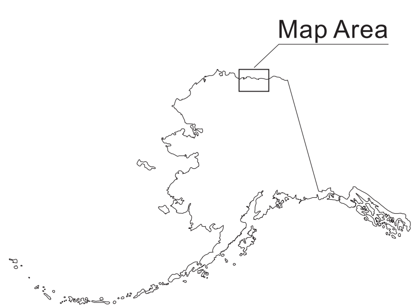
Since the formation of the continental margin in the Early Cretaceous (Grantz and May, 1993), the northern flank of the Barrow Arch has been dominated by passive-margin subsidence and sedimentation. To the south, compressional forces in the Jurassic to Early Cretaceous caused thrust faulting in what is now the present-day Brooks Range. Sediments from the thrust faulted blocks in the Brooks Range poured into the Colville basin, progressively filling it from the south, forming the Brookian Sequence. The post Albian Brookian sequence records the progressive filling of a large east-west trending foreland basin (the Colville Trough) formed in response to thrust loading from the Brooks Range, a large north vergent fold and thrust belt. During latest Cretaceous and Paleocene time, deposition of Brookian sediments filled the Colville Trough, eventually overstepping the Barrow Arch and spread out onto Alaska's continental margin. Petroleum accumulations in the Brookian Sequence are found throughout the North Slope basin. Fields and hydrocarbon accumulations include: the West Sak, Schrader Bluff, Ugnu, Flaxman Island, Badami, and the Outer Continental Shelf (OCS) accumulation at Hammerhead (Weimer, 1987).

The onshore present-day geology of the sale area is comprised of a thick section of unconsolidated Quaternary sediments (Brown and Kreig, 1983) that have been deposited within the last million years. These sediments comprise the Gubik Formation that unconformably overlie the weakly cemented sediments of the upper Brookian Sequence. Most Quaternary deposits are unconsolidated sand and gravel composed of reworked Brookian sediments and reworked sediments from the present day Brooks Range. Overlying these deposits are gravels, sands, ice-rich silts, and sandy silts (that include variable amounts of organic matter) that are deposited by the numerous rivers on the North Slope. In addition to the extensive fluvial deposits, there are local areas of modern eolian deposits (sand dunes) that are derived from river silts (Brown and Kreig, 1983).

During middle to late Devonian time, a mountain building and rifting event uplifted the Franklinian sequence, deforming and metamorphosing the rocks in the process. Sediments from the uplifted Franklinian sequence spread southward into the large arctic basin (epicontinental shelf). This process continued through to late Cretaceous time. These northerly sourced sediments formed the Ellesmerian Sequence (Moore, et al., 1994).

FIGURE 2.3 North Slope / Beaufort Sea Activity





The Ellesmerian Sequence is the most important geologically in terms of petroleum production. Formations within the Ellesmerian Sequence form the primary petroleum reservoirs at Prudhoe Bay, and Endicott. The Ellesmerian Sequence contains marine carbonates and quartz and chert rich clastic rocks, representing about 150 million years of deposition (Mississippian through Triassic). From the center of the Colville Basin, the Ellesmerian thins to the south due to depositional distance from its source and it thins to the north due to subsequent uplift and erosion (Moore, et al., 1994).

Rifting of the continental mass dominated the geology by the end of the late Jurassic to late Cretaceous periods. The northern continental source for the Ellesmerian sediments supplied less and less sediment to the arctic basin as time passed. Uplift and faulting of the Franklinian and Ellesmerian sequence formed fault block and grabbens (low areas between fault blocks). These grabbens were filled by sediments from the locally uplifted or upfaulted Ellesmerian and Franklinian sequences, forming the Rift Sequence (Craig, et al., 1985). It is also at this time that the Barrow Arch formed along the present day Beaufort Coast. Sedimentation from the north eventually ended sometime in the Late Cretaceous and the following period of non-deposition along with continued uplift along the Barrow Arch created a regional Lower Cretaceous Unconformity (LCU) which becomes angular approaching the Barrow Arch from the south. To the north of the Barrow Arch the Ellesmerian sequence is absent. The LCU is an important migration and accumulation element for most of the oil fields on the North Slope including Prudhoe Bay (Jamison, et al., 1980).

To the south, compressional forces in the Jurassic to early Cretaceous caused thrust faulting in what is now the Brooks Range. Sediments from the thrust faulted blocks in the Brooks Range poured into the Colville Basin, progressively filling it from the south, forming the Brookian Sequence. Brookian sediments filled the Colville Basin and spread out over the Barrow Arch and onto Alaska’s continental margin during the upper Late Cretaceous through Tertiary time. Petroleum accumulations in the Brookian Sequence are found throughout the North Slope basin, including at West Sak, Schrader Bluff, Flaxman Island, and the Outer Continental Shelf (OCS) accumulation at Hammerhead (Weimer, 1987).

Onshore present day geology of the sale area is, in general, comprised of a thick section of unconsolidated Quaternary sediments (Brown and Kreig 1983), deposited within the last 1 million years. These sediments are probably of the Gubik Formation which unconformably overlies the weakly cemented sediments of the upper Brookian Sequence. Most Quaternary deposits are unconsolidated sand and gravel composed of reworked Brookian sediments, along with materials from the present day Brooks Range. Overlying these deposits are ice-rich silts and sandy silts (1.5 m to 2.5 m thick at Prudhoe Bay) that include variable amounts of organic matter, which are deposited by the numerous rivers on the North Slope. In addition to these fluvial deposits are local areas of eolian deposits (sand dunes) derived from river silts (Brown and Kreig, 1983).

2. Petroleum Potential

ADNR has determined that the sale area, in general, has moderate to high petroleum potential. This represents ADNR’s assessment of the oil and gas potential of the area and is based on a resource evaluation made by the state. This resource evaluation involves several factors including geology, seismic data, exploration history of the area, and proximity to known hydrocarbon accumulations.

In order for an accumulation of hydrocarbons to be recoverable, the underlying geology must be favorable. This may depend on the presence of source and reservoir rock; the depth and time of burial; and the presence of migration routes and geologic traps or reservoirs. Source rocks are organic rich sediments, generally marine shales, that have been buried for a sufficient time, and with sufficient temperature and pressure to form hydrocarbons. As hydrocarbons are formed, they will naturally progress toward the surface if a migration route exists. An example of a migration route might be a permeable layer of rock in contact with the source layer, or fractures which penetrate organic rich sediments. A hydrocarbon reservoir is permeable rock that has been geologically sealed at the correct time to form a “trap.” The presence of migration routes therefore affect the depth and location where oil or gas may pool and form a reservoir. For a hydrocarbon reservoir to be producible, that is, economic, the reservoir rock must be of sufficient thickness and quality (good porosity—number of pore spaces per volume, and permeability—a rock’s capacity for transmitting a fluid), and must contain a sufficient volume or fill of hydrocarbons.

The Beaufort Sea has all these favorable geologic conditions and, considering the exploration history of the area, the chances of finding undiscovered petroleum reservoirs are very good. However, the remaining undiscovered reservoirs are expected to be non-economic to marginally economic accumulations under current market conditions. In light of this, the petroleum potential of this basin for the discovery of new fields is moderate.

The process of evaluating the oil and gas potential for state lease sale areas, such as the Beaufort Sea, involves the use of seismic data and well engineering information which, by law, the division must keep confidential under AS 38.05.035(a)(9)(C). In order to protect these data, the division must generalize the assessment which is made public.

3. Climate

Surface conditions in the Arctic vary dramatically. In summer, the climate is generally mild. The three-month ice-free season is critical to biological productivity. In contrast, winters are severe, forcing many species to migrate south.

a. Precipitation

Along the Beaufort Sea coast, the amount of precipitation is low. Air temperature controls how much moisture the air holds as a vapor. Extremely cold air can contain only very small amounts of water vapor. The result is low precipitation. Therefore, the region is classified as a desert—a desert of frozen land (AEIDC, 1975:18). Precipitation ranges from 13 cm at Barrow to 18 cm at Barter Island. (MMS, 1996: III-A-2). Oliktok Point, adjacent to the sale area, has an average of 18.8 cm per year. Most precipitation occurs during summer as rain. Average annual snowfall is only 12 inches along the coast (AEIDC, 1975:18).

b. Temperature

The Arctic receives most of its heat energy during the short summer months. The decrease of heat energy in fall and winter is rapid at extreme northern latitudes. Areas of extensive cloud cover receive much less heat energy. The length of the day is also a factor, since longer days produce more radiation. The sun angle in the Arctic is low even during long days. As a result, the sun's rays pass through a greater depth of atmosphere which absorbs some of the energy before it reaches the surface. Although the Arctic Ocean and Beaufort Sea are frozen for 10 months of the year they have a modifying effect on coastal temperatures. February is the coldest month. The average minimum temperature is approximately -25° F along the coast. July is the warmest month with an average maximum temperature of 45° F (AEIDC, 1975:15).

The freezing and thawing of tundra, watery marshes, and lakes affect all outdoor activity in the Arctic. Surface transportation in summer is limited to where gravel roads have been constructed. In winter when the tundra, marshes, and lakes freeze sufficiently, almost any kind of equipment can travel with little or no damage to the tundra (AEIDC, 1975:21).

c. Winds

Surface wind conditions affect nearshore currents, the movement of ice floes and oil spills, and the formation and break-up of sea ice. Winds also influence the timing of migratory activity in animals, and the relative safety of subsistence harvesting and oil and gas activities in the Arctic (Kozo, 1984). Surface wind speeds along the coast are persistent and strong compared to those in more interior regions. Arctic coastal wind speeds of 30 to 50 kts. are common during winter months. The average annual wind speed is 10.6 kts. at Barrow and 11.5 kts. at Barter Island (AEIDC, 1975:19). A semipermanent area of high pressure is centered approximately 600 miles north of the Alaska Arctic coast. Air continually flows south from this area of higher pressure as a north wind. By the time it reaches the Beaufort sea coast its direction is between northeast and east because of the rotation of the earth (AEIDC, 1975:19). Wind direction is predominately easterly but shifts to westerly from January to April. Part of this shift is due to piling up of air against the Brooks Range. Sea breezes (air moving inland in response to unequal heating across the coastline) control at least 25 percent of the summer surface wind direction and extend to at least 20 km offshore (MMS, 1996: III-A-3)(Kozo, 1984:33).

4. Oceanography, Sea Ice, and Permafrost

Life, both residential and migratory in the sale area is supported by the coastal zone habitat. The productivity and extent of coastal habitats are dependent on physical processes which shape and move the coast and barrier islands, and influence the circulation of marine waters. These coastal processes are driven by the changing seasons and the ever-present polar ice cap.

a. Oceanography

Marine waters overlying the sale area are generally shallow; most of the area is within the 33-foot isobath. The continental shelf along Alaska's north coast is relatively narrow. The distance from the shore to the shelf break ranges from approximately 30 to 60 miles. Barrier Islands and shoals comprised of gravel or tundra lie within the sale area and include the Eskimo, Jones, Spy, Midway, McClure, Return, Stockton, and Maguire island chains as well as Thetis, Leavitt, Pingok, and Flaxman islands. Due to longshore drift (a prevailing current parallel to the coastline), some barrier islands are shifting westward at rates of 60 to 100 ft. per year and landward 10 to 20 ft. per year (MMS, 1987: III-2).

Tides along the northern Arctic coast are very small, averaging about 1 ft. Sea level is sometimes affected by storm surges, most frequently in summer and fall, with surges changing sea level by as much as one to three meters (MMS, 1987: III-6 Sale 97). The rates of coastal erosion vary from year to year depending on the timing of sea ice breakup, the timing of summer and autumn storms, the composition of the coastal bluffs, beach width and the morphology of the adjacent sea floor. Most erosion occurs in late summer and autumn. Annual coastal erosion rates range from approximately 10.3 m at Harrison Bay to 1.5 m at Flaxman Island. In some areas, like the Colville River Delta, the shoreline may be advancing (MMS, 1996: III-A-1).

Sea temperatures are cold throughout the year, ranging from -1º to -2º C in winter under the ice to just above freezing in summer. Sea temperatures off all pack-ice zones are markedly cooler (AEIDC, 1975:32).

Seasonal freezing and melting are the major influences affecting surface water characteristics in the arctic seas (AEIDC, 1975:32). Nearshore Beaufort Sea waters are relatively warm, turbid, brackish, and shallow. This zone of brackish water is formed each spring when coastal plain rivers discharge warm freshwater into the Beaufort Sea. The width and depth of this zone varies depending on freshwater input, water currents, winds, and topography (Craig, et al., 1984:269). The mixing of these water masses results in a great diversity and abundance of zooplankton; these zooplankton and arctic cod support large numbers and species of fish and wildlife within the sale area (ADNR, 1992:6).

The salinity of the Beaufort Sea varies both geographically and seasonally from 28 to 32 parts per thousand. The relatively warmer water of low salinity from large rivers affects the salinity in the vicinity of the deltas. Salinity is much higher in these areas in winter as river flow decreases or increases. Seawater samples from under the ice in spring show salinity values of 30 to 33 parts per thousand (ppt) in Harrison Bay and up to 40 ppt under the ice in the Colville River delta. Less saline waters exist behind barrier islands, in lagoons, and in river deltas. These estuarine type waters are enriched by terrestrial nutrients and support a productive biological community (AEIDC, 1975:32).

Conversely, salinity for nearshore waters may be lower. During one summer, salinity for Mikkelsen Bay measured uniformly throughout the bay, and averaged between 16.9 and 23 ppt. During the 1994 study year, average salinity was lowered by 2 to 5 ppt after a rain storm (Fechhelm, et al., 1996:6-9). Historical data indicate that salinity levels, for example in Prudhoe Bay, vary considerably from year to year (Griffiths, et al., 1995:34).

Sediments in the Beaufort Sea waters come from river runoff at spring breakup and the rains of late summer, coastal erosion, scour of the sea bottom by moving ice, and from freezing of bottom sediments into fast ice. The surficial sediments consist predominately of clay and silt-size particles underlain by ice-bonded sandy gravel in some areas (MMS, 1996: III-A-3)(Morack & Rogers, 1984:270). The concentration and size of sediments vary greatly with local geological conditions and season. Largest sediment concentrations and coarsest sizes are carried during spring ice breakup and in severe storms. Coarse materials are often carried offshore by ice-rafting (AEIDC, 1975:32).

The surface circulation of the Beaufort Sea is dominated by a clockwise gyre in the Arctic basin, centered midway between Alaska and the North Pole. This prevailing current moves both water and ice shoreward throughout most of the year. However, over short periods of time nearshore surface currents are extremely variable. In late summer and fall easterly and offshore winds produce surface currents countering the prevailing Arctic gyre. This results in a variable period of relatively ice-free waters (AEIDC, 1975:25).

The speed, direction, and persistence of summer winds determine whether freshwater river runoff accumulates or dissipates in the nearshore Beaufort Sea. The temperature, turbidity, and salinity of nearshore waters is also influenced by the level of mixing of nearshore water with colder offshore water in the shallow bays and lagoons; a process driven by summer winds. The presence or absence of prevailing winds in a given year has been correlated with anadromous fish migration (into the sale area) success in subsequent years (Griffiths, et al., 1995:30). For more detail on the effects of coastal processes on Arctic fish, see Chapter Three.

b. Sea Ice

For nine months of the year, typically from November through July, marine waters are covered with ice. Within the sale area, most ice is land fast ice which is anchored to shore and is relatively stable in comparison to the shear zone and pack ice further offshore (ADNR, 1991:7). Landfast ice freezes to the bottom in shallow waters near land, and by the end of winter may extend outward to the 30- to 60-ft. depth contour where it may reach a maximum thickness of about 6 ft. (AEIDC, 1975:27). Wind and water stresses during freeze-up and breakup may result in deformations that take the shape of pileups and rideups on the coastal and island beaches. These frequently extend up to 20 m inland from the shoreline (MMS, 1996: III-A-10).

Seaward of the landfast ice is the shear zone or stamukhi. Shear zone ice forces are extremely dynamic and constantly produce open water ridges or leads that freeze and form new ice which in turn is deformed by pressure. The region of most intense ridging occurs in Beaufort Sea waters that are 15 to 45 m deep. As shear zone ice moves, it may gouge the sea bottom. The number and appearance of ice gouges depend on sediment type and age, the shape of the ice and depth of the water (AEIDC, 1975:27)(MMS, 1996: III-A-11).

The pack ice zone lies beyond the shear zone and consists predominantly of multiyear ice floes from 6 to 12 ft. thick that are constantly in motion. Multi-year ice is that which has survived more than one melt season. In summer they are surrounded by open water, thin ice or bits and fragments and in winter by first-year ice. The long-term ice movement is from east to west in response to the Beaufort Gyre. Often, the Beaufort Sea pack ice contains large ice floes or ice islands that originated from the Ellesmere Ice Shelf. They vary in size from a few thousand square yards to 300 sq. mi.. When subjected to pack ice pressures in shallow waters, their keels extensively gouge the sea bottom (AEIDC: 1975: 27)(MMS 1996: III-A-11).

c. Permafrost

Permafrost consists of any soil or other superficial deposit, including bedrock, that has been colder that 0º C for two or more years. Permafrost soils may be nearly ice free in coarse, unsaturated materials and may contain more than 50 percent water in finer grain saturated soils. Alaska has two types of permafrost classified as continuous or discontinuous. Continuous permafrost implies that the ground is frozen over nearly all the landscape and is colder than -5º C at the depth below annual seasonal temperature changes (depth varies based on rock type and water content but is about 15 m). Discontinuous permafrost is ground that is between 0º C and -5º C and as the term suggests, is not continuous. In discontinuous zones of permafrost, ground on south facing slopes and under large bodies of water are usually not frozen. Generally north of Atigun Pass (crest of the Brooks Range), the permafrost is continuous (Brown and Kreig, 1983). Heading offshore the permafrost becomes progressively more discontinuous (MMS, 1996).

Near Prudhoe Bay, permafrost extends to a depth of about 600 m which is the probable case for most all of the onshore portion of the sale area (Brown and Kreig, 1983) (Combellick, 1994, citing to Collett and others 1989). The depth of the active layer, or the layer of seasonal thaw is generally less than 0.9 m and 1.8 m beneath active stream channels. Ice content varies from minor segregated ice to massive ice in the form of ice wedges and pingos. Offshore, a large area of permafrost occurs off the Sagavanirktok River and possibly near Harrison Bay. Other areas of offshore permafrost include the 2-meter isobath zone, which is overlain by bottomfast ice in the winter; areas between the barrier islands and the shoreline; and on some of the barrier islands. However, permafrost may exist in other isolated places offshore to depths several hundred meters beneath the seafloor (MMS, 1996). It is generally accepted that permafrost does not extend offshore beyond the 90-meter isobath.

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